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DRAG EFFECTS OF VARIOUS METHODS OF CARRYING FUSELAGE MOUNTED ST--ETC(U)
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NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Washington, D.C. 20007

DRAG EFFECTS OF VARIOUS METHODS OF CARRYING FUSELAGE MOUNTED STORES (U)

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Report C-2939

DRAG EFFECTS OF VARIOUS METHODS OF CARRYING FUSELAGE MOUNTED STORES (U)

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Naval Ship Research and Development Center
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(6) DRAG EFFECTS OF VARIOUS METHODS OF CARRYING FUSELAGE MOUNTED STORES.

(Title Unclassified

by

(10) Jonah Ottensoser

(9) Research and development rept.,

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SYMBOLS

C_D'	drag coefficient $\left(\frac{\text{drag}}{qS_w}\right)$
C_L	lift coefficient $\left(\frac{\text{lift}}{qS_w}\right)$
C_m	pitching moment coefficient $\left(\frac{\text{pitching moment}}{qS_w\bar{c}}\right)$
$\bar{c}$	aircraft mean aerodynamic chord, in inches
ΔD	full-scale incremental drag, in pounds (difference between drag of dirty aircraft and corresponding reference aircraft, extrapolated to full scale)
M	free-stream Mach number
q	free-stream dynamic pressure
S_w	aircraft wing planform area
α	angle of attack, in degrees

SUMMARY

(U) The third in a series of scale-model wind tunnel tests to determine the effect of fuselage mounted stores on the drag of an attack aircraft is reported. This phase investigates stores mounted semi-submerged, tangent, and on short and long pylons on the fuselage of a low, 25° sweep wing. Additional configurations include stores carried on a fuselage mounted Multiple Ejection Rack (MER) as well as on the fuselage without wings. Also included in this report is the drag of partially loaded configurations. The angle of attack ranged from -2° to 4° and the Mach number from 0.60 to 0.90.

(C) The results of this phase indicate that adding one-half bomb diameter depth to the underside of the fuselage had little effect on drag. Empty cavities were found very detrimental to drag while semi-submerging of the stores produced the least incremental drag of the different types of carriage examined. In addition, it was found that the displacement of the stores from the underside of the fuselage tended to increase the incremental store drag. It was also observed that the first row of fuselage mounted stores produced about one-half the incremental drag of the full load.

INTRODUCTION

(U) An investigation into the effect of fuselage mounted stores on the drag of aircraft cruising at high subsonic speeds was initiated at the Naval Ship Research and Development Center early in 1966. This study was prompted by the requirements to develop a fighter/attack airplane (VFAX) for use by the Navy.

(U) Two earlier reports (References 1 and 2) describe the results of previous wind tunnel tests of various aspects of fuselage store carriage. This report, the third in the series, presents the results of further investigations into the general area of fuselage mounted stores.

(U) In this investigation the parent aircraft was represented by a basic body and a low, 25° sweep wing. Also, the basic body was tested without wings and was modified by increasing its height by one-half the maximum diameter of a Mk 82 bomb to allow for semi-submerging of that bomb.

(U) Configurations examined included carriage of Mk 82 and Mk 81 bombs with Snakeye tails tangent to the underside of the airplane and on long and short fuselage pylons. In addition, Mk 81 bombs were carried on

fuselage mounted Multiple Ejection Racks and Mk 82 bombs were carried semi-submerged. Both partial and full loads were tested in evaluating the various types of store carriage. Tests were conducted at Mach numbers of 0.60, 0.70, 0.80, 0.85, and 0.90.

(U) This study was initiated by Reference 3 in which the Aerodynamics Laboratory of the Naval Ship Research and Development Center was requested to review drag and launch/release characteristics, and perform suitable studies and tests required for optimizing store carriage on the VFAX aircraft.

MODELS

(U) The wing-body model consists of a rectangular cross-section fuselage rounded at the corners and faired to a point at the nose and 25° swept wing with a NACA 64A008 airfoil section. To provide the space necessary for semi-submerging stores, the body height was increased one-half of the maximum diameter of a Mk 82 bomb. The additional height was added to the bottom of the fuselage so that the distance between the wing and the top of the fuselage remained the same. The additional volume was faired smoothly into the nose. Details of the wing body configurations are shown in Figure 1 and a plot of their area distributions are shown in Figure 2.

(U) The external stores tested were 0.10 scale models of the Mk 81 and Mk 82 bombs with Snakeye tails. Figure 3 gives pertinent information about these bombs.

(U) The long pylons used had a depth of one-half the maximum bomb diameter of a Mk 82 bomb which is equivalent to six-tenths of the maximum bomb diameter of a Mk 81 bomb. The short pylons had a depth equal to one-quarter and three-tenths of the same respective bomb diameters. Figure 4 gives pertinent information about the pylons.

(U) The MER was mounted tangent to the bottom surface of the model. Some details of this configuration are given in Figure 4. Figure 5 shows some typical configurations with diagrams locating the exact store positions. Table 1 lists all the configurations tested in this phase. In all cases stores were mounted parallel to the wing body center line.

TESTS AND MEASUREMENTS

(U) The tests were conducted in the NSRDC 7- by 10-Foot Transonic Wind Tunnel described in detail in Reference 4. Configurations investigated

include: semi-submerged stores, fuselage mounting of stores on various length pylons and on Multiple Ejection Racks, fuselage mounting of stores on a body without wings, gapping and staggering of store loads and partial store loads. Reynolds number variation was also investigated by changing tunnel conditior . Configurations discussed in this report will be confined to a Reynolds number of about 3×10^6 per foot to enable early publication and to limit the subject to that of drag effects. The results obtained at a higher and lower Reynolds number will be discussed in a subsequent paper. However, for information purposes the list in Table 1 contains all of the configurations tested in this phase.

(U) All tests were conducted with the model mounted on a cantilevered sting support system through a six-component internal strain gage balance. Data from all components were recorded and reduced to coefficient form but only the three longitudinal components are presented in Figure 6.

(U) Test conditions included Mach numbers of 0.60, 0.70, 0.80, 0.85, and 0.90 and an angle of attack range from -2° to 4°. Transition was fixed on the aircraft wing at 10 percent of the chord and on the stores and fuselage at 10 percent of their respective lengths with 1/8-inch wide strips of number 90 carborundum grit.

CORRECTIONS AND ACCURACY

(U) Angles of attack have been corrected for deflection of the model support system and balance and are within $\pm 0.1^\circ$. Lift, drag, and pitching moment coefficients have an accuracy of ± 0.004, ± 0.005, and ± 0.001, respectively, at a Mach number of 0.80. The Mach numbers reported are within ± 0.003 and since the blockage of the model is less than 0.5 percent of the test section area, no corrections have been made for wall effects. Drag data have been corrected for base pressure effects on the aircraft model.

RESULTS AND DISCUSSIONS

(U) The study of the incremental drag of fuselage mounted stores discussed initially in References 1 and 2 has continued and some results of the third phase are presented herein.

(U) The incremental drag, $\Delta D/q$, used in comparing the drag of the different modes of store carriage was calculated by subtracting the drag coefficient of a reference configuration from that of a corresponding configuration with stores. This difference is then multiplied by the model wing area

and scale factor to give full scale $\Delta D/q$ in square feet. For all stores/pylons carried on the standard wing/body the reference configuration was the clean standard wing/body; for stores carried on the standard body without wings the reference configuration was the clean standard body and for semi-submerged stores the reference configuration was the enlarged body/wing combination with cavities faired.

(C) Of the three reference configurations the model without wings had the lowest drag, whereas the drag of the standard wing/body model and the enlarged body/wing (with cavities faired) had about equal drag as shown in Figure 7. Drag rise begins for both of the latter two models at a Mach number of about 0.8. Figure 7 also contains a curve for the drag of the enlarged body/wing without faired cavities. For this case the drag increases about 50 percent above that of the model with cavities faired. From Figure 8 one sees that adding pylons to the underside of the fuselage produces only a small drag increment with the deeper of the two pylons producing a larger drag increment.

(C) Figures 9 and 10 present the incremental drag of the various modes of carriage of 9 Mk 82 and 12 Mk 81 bombs, respectively. As the stores were moved further away from the underside of the fuselage the incremental drag increased. Thus the lowest drag was obtained by semi-submerging Mk 82 bombs or tangent-mounting Mk 81 bombs and the highest by mounting the stores on long pylons for all cases of stores in the same horizontal plane. Actually, the highest drag for the 12 Mk 81 bombs was obtained by mounting them on two fuselage MER's as shown in Figure 10.

(C) From Figures 9 and 10, it is evident that there is a substantial incremental drag rise for Mach numbers greater than about 0.85 for stores carried external to the underside of the fuselage of the wing/body combination. However, for stores carried semi-submerged this incremental drag rise is not present.

(C) Figure 11 shows the results of longitudinally spacing 12 Mk 81 bombs in the same manner they were spaced for the data contained in Figure 10 of Reference 2 and as shown in Figure 5 of this report except that for this report the stores were also mounted on pylons. Again, the same detrimental effect of longitudinal spacing is revealed.

(C) Figure 12 shows the effect of adding stores to a body without wings. The incremental drag of both 9 Mk 82 and 12 Mk 81 tangent mounted stores is lower for the body without wings than on the wing/body combination. This is more marked for 9 Mk 82 than for 12 Mk 81 bombs.

(C) There are two possible explanations for this drag difference. First, the area distribution of the body without wings when compared to the winged body is much smoother as shown in Figure 2. Thus, the addition of stores to the wingless body simply raises the flat portion of the area distribution curve, while the addition of stores to the already poor area distribution of the wing body distorts and raises the peak of the curve and thus accents an already poor situation. This explanation is supported by the fact that at higher Mach numbers where the area rule really takes effect, the difference in drag becomes quite large.

(C) A second possible explanation is that the proximity of the wing to the underside of the fuselage has a detrimental effect on incremental drag. This contention is supported by the results portrayed in Figure 9 of Reference 2 where stores carried on a low wing model had somewhat higher drag than the same stores carried on a high wing model although the area distribution of the two configurations are the same. In all likelihood the exact description of what is really happening involves both explanations.

(C) Figure 12 also contains a plot of the incremental drag of 12 Mk 81 bombs in a staggered array on a body without wings. Here, as in Figure 9 of Reference 2, no appreciable effect is seen as a result of staggering the stores.

(C) Figures 13 and 14 are the plots of the incremental drag of partial and full loads of Mk 82 and Mk 81 bombs, respectively. The store loads were built up by adding adjacent rows in a rearward direction. From these figures it is evident that the first row of stores produces about 50 percent of the drag of the full load. The remaining 50 percent is divided between the second and third row of stores with the second row producing somewhat more drag than the third. Of note is the incremental drag rise for the full and two-thirds full loads of bombs; the incremental drag for these two cases converges at the higher Mach numbers tested and in some cases crosses over. In general the smallest penalties are paid in adding rows of tangent mounted stores.

(C) The above holds true for all cases except the semi-submerged mode of carriage. For this case the empty cavities are the dominant drag producing factor. The incremental drag of three Mk 82 bombs with six empty cavities is greater than nine Mk 82 bombs with no cavities and the latter configuration has only slightly more drag than six Mk 82 bombs with three cavities.

CONCLUSIONS

(C) Based on the data obtained during this series of tests the following conclusions are drawn:

1. The additional fuselage depth required to semi-submerge stores had little effect on drag.

2. Empty cavities are very detrimental to drag. The unfilled cavities had about twice the incremental drag of the cavities filled with stores.

3. The first row of stores produces about 50 percent of the incremental drag of a full load for all cases except semi-submerging.

4. The incremental drag of the stores tends to increase as the stores are moved further away from the fuselage with the lowest incremental drag for the semi-submerged stores and the highest for the stores on long pylons.

5. Longitudinal spacing had a detrimental effect on incremental store drag while staggering of the stores had little effect.

Aerodynamics Laboratory
Naval Ship Research and Development Center
Washington, D. C. 20007
August 1968

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Table 1

Configuration Description

Configuration	Wing	Body	Type of Store	Method of Fuselage Carriage	Number of Stores				Reynolds Number	Graph in Figure 6
					Total	Forward	Center	Aft		
STD	LW 25°	STD	-	-	0	0	0	0	3.4×10^6	(a)
STD-NW	None	STD	-	-	0	0	0	0	3.4×10^6	(b)
SEMI-SUB	LW 25°	Cavities	-	-	0	0	0	0	3.4×10^6	(c)
SEMI-SUB FAIRED	LW 25°	Cavities Faired	-	-	0	0	0	0	3.4×10^6	(d)
9 SHORT PYLONS	LW 25°	STD	(Short Pylons)	-	0	0	0	0	3.4×10^6	(e)
9 LONG PYLONS	LW 25°	STD	(Long Pylons)	-	0	0	0	0	3.4×10^6	(f)
9-82 SEMI-SUB	LW 25°	Cavities	Mk 82	Semi-Sub	9	3	3	3	3.4×10^6	(g)
9-82 TANGENT	LW 25°	STD	Mk 82	Tangent	9	3	3	3	3.4×10^6	(h)
9-82 TAN-NW	None	STD	Mk 82	Tangent	9	3	3	3	3.4×10^6	(i)
9-82 SP	LW 25°	STD	Mk 82	Short Pylons	9	3	3	3	3.4×10^6	(j)
9-82 LP	LW 25°	STD	Mk 82	Long Pylons	9	3	3	3	3.4×10^6	(k)
6-82 SEMI-SUB	LW 25°	Cavities	Mk 82	Semi-Sub	6	3	3	0	3.4×10^8	(ℓ)
6-82 SP	LW 25°	STD	Mk 82	Short Pylons	6	3	3	0	3.4×10^6	(m)
6-82 LP	LW 25°	STD	Mk 82	Long Pylons	6	3	3	0	3.4×10^6	(n)
3-82 SEMI-SUB	LW 25°	Cavities	Mk 82	Semi-Sub	3	3	0	0	3.4×10^6	(o)
3-82 SP	LW 25°	STD	Mk 82	Short Pylons	3	3	0	0	3.4×10^6	(p)
3-82 LP	LW 25°	STD	Mk 82	Long Pylons	3	3	0	0	3.4×10^6	(q)

Table 1 (Continued)

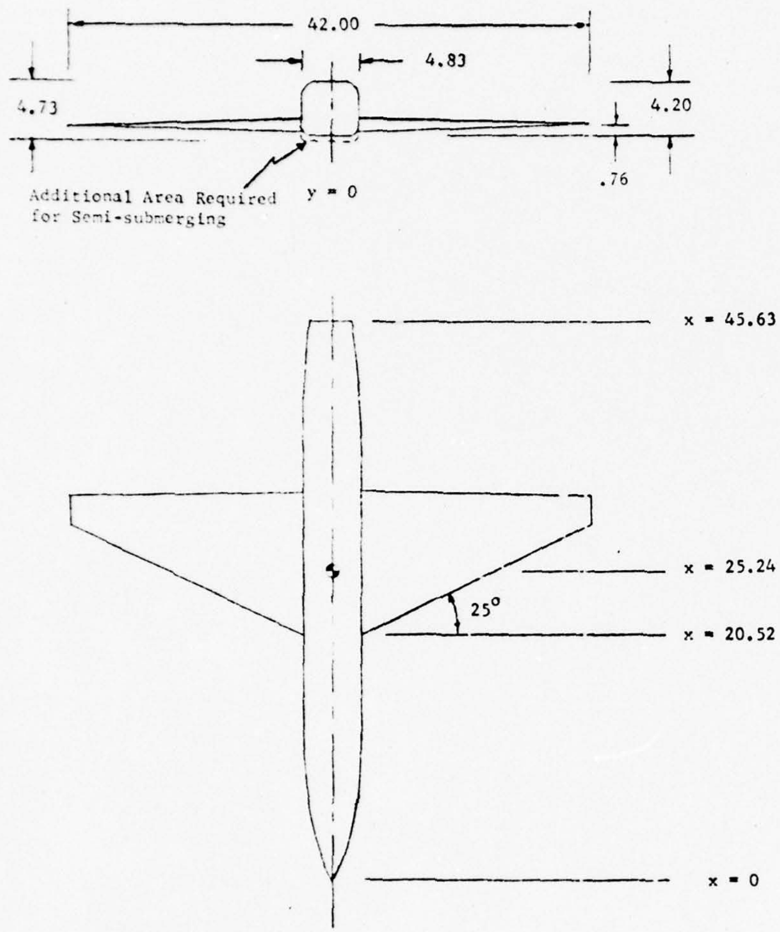
Configuration	Wing	Body	Type of Store	Method of Fuselage Carriage	Number of Stores				Reynolds Number	Graph in Figure 6
					Total	Forward	Center	Aft		
12-81 TAN	LW 25°	STD	Mk 81	Tangent	12	4	4	4	3.4×10^6	(r)
12-81 TAN-NW	None	STD	Mk 81	Tangent	12	4	4	4	3.4×10^6	(s)
12-81 STAG-NW	None	STD	Mk 81	Tangent Staggered	*12	-	-	-	3.4×10^6	(t)
12-81 MER	LW 25°	STD	Mk 81	MER	*12	-	-	-	3.4×10^6	(u)
12-81 SP	LW 25°	STD	Mk 81	Short Pylon	12	4	4	4	3.4×10^6	(v)
12-81 SP-SPACED	LW 25°	STD	Mk 81	Short Pylon Spaced	*12	4	4	4	3.4×10^6	(w)
12-81 LP	LW 25°	STD	Mk 81	Long Pylon	12	4	4	4	3.4×10^6	(x)
12-81 LP-SPACED	LW 25°	STD	Mk 81	Long Pylon Spaced	*12	4	4	4	3.4×10^6	(y)
8-81 SP	LW 25°	STD	Mk 81	Short Pylon	8	4	4	0	3.4×10^6	(z)
8-81 LP	LW 25°	STD	Mk 81	Long Pylon	8	4	4	0	3.4×10^6	(aa)
4-81 SP	LW 25°	STD	Mk 81	Short Pylon	4	4	0	0	3.4×10^6	(bb)
4-81 LP	LW 25°	STD	Mk 81	Long Pylon	4	4	0	0	3.4×10^6	(cc)
STD-TSV	LW 25°	STD	-	-	0	0	0	0	4.9×10^6	(Not Presented)
STD-NW-TSV	None	STD	-	-	0	0	0	0	4.9×10^6	(Not Presented)
SEMI-SUB-TSV	LW 25°	Cavities	-	-	0	0	0	0	4.9×10^6	(Not Presented)

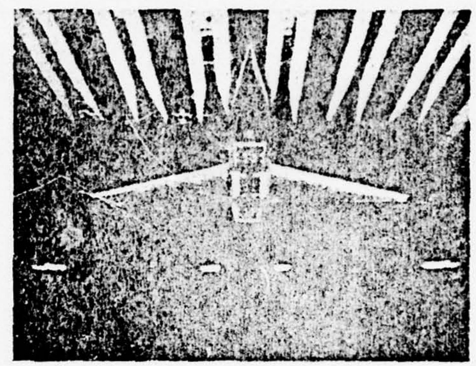
*See Figure 5 for the exact location of stores.

Table 1 (Concluded)

Configuration	Wing	Body	Type of Store	Method of Fuselage Carriage	Number of Stores				Reynolds Number	Graph in Figure 6
					Total	Forward	Center	Aft		
9-82 SEMI-SUB-TSV	LW 25°	Cavities	Mk 82	Semi-Sub	9	3	3	3	4.9×10^6	(Not Presented)
9-82 TAN-TSV	LW 25°	STD	Mk 82	Tangent	4	3	3	3	4.9×10^6	(Not Presented)
12-81 TAN-TSV	LW 25°	STD	Mk 81	Tangent	12	4	4	4	4.9×10^6	(Not Presented)
STD-EVAC	LW 25°	STD	-	-	0	0	0	0	1.7×10^6	(Not Presented)
SEMI-SUB-EVAC	LW 25°	Cavities	-	-	0	0	0	0	1.7×10^6	(Not Presented)
9-82 SEMI-SUB-EVAC	LW 25°	STD	Mk 82	Semi-Sub	9	3	3	3	1.7×10^6	(Not Presented)
9-82 TAN-EVAC	LW 25°	STD	Mk 82	Tangent	9	3	3	3	1.7×10^6	(Not Presented)
12-81 TAN-EVAC	LW 25°	STD	Mk 81	Tangent	12	4	4	4	1.7×10^6	(Not Presented)

Note: All dimensions are in inches.





LW 25° Model Mounted in Tunnel

Airfoil	NACA 64A006
Mean Aerodynamic Chord	8.30
Tip Chord	1.85
Taper Ratio	0.15
Aspect Ratio	6.00
Area (Square Feet)	2.05
Incidence	0°
Dihedral	0°

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Figure 1 - Geometric Details of the Low Wing 25° Model

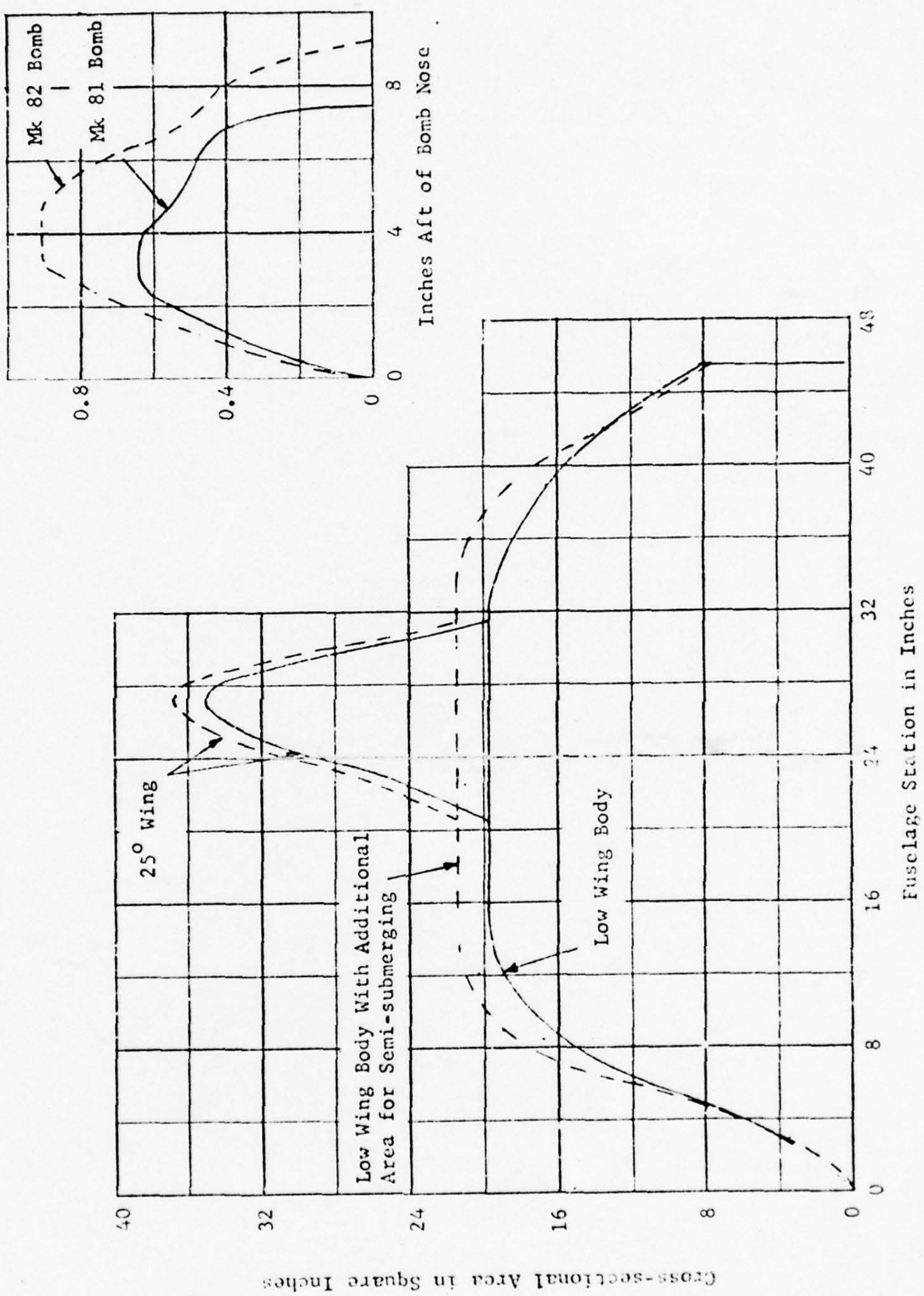
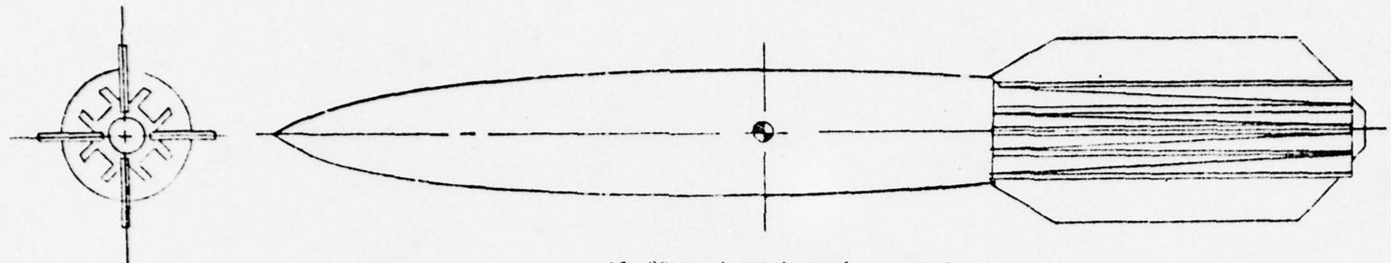


Figure 2 - Area Distributions of Aircraft Models and Stores

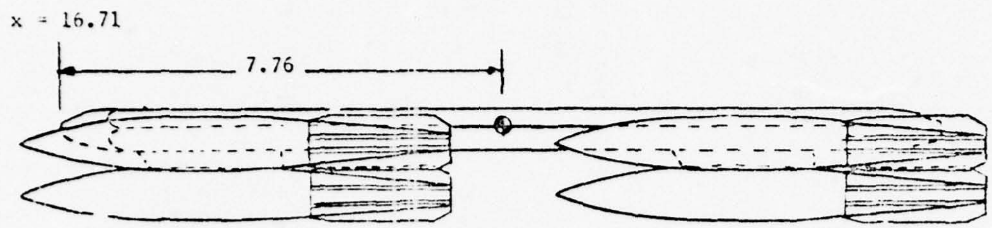


Mk 82 Bomb With Snakeye Tail

Mk 81 Bomb With Snakeye Tail

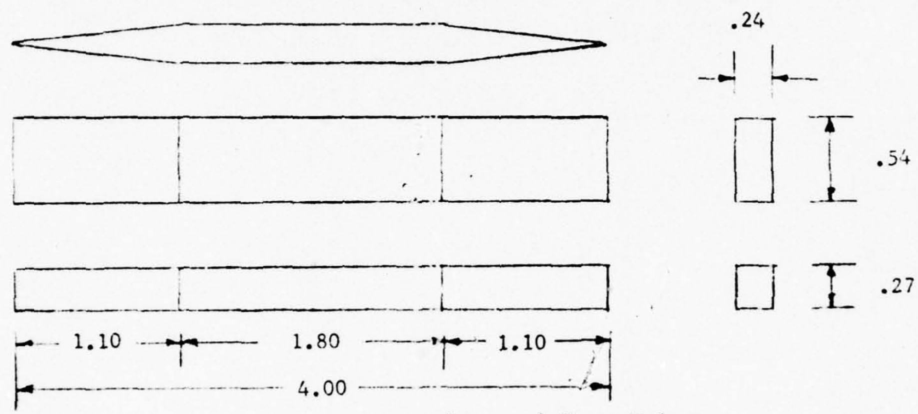
	Mk 82	Mk 81
Length (in.)	9.260	7.506
Diameter (in.)	1.075	0.900
Fineness Ratio	8.614	8.340
Max Area (sq ft)	0.00631	0.00442

Figure 3 - Geometric Characteristics of Mk 82 and Mk 81 Bombs with Snakeye Tails



6 Mk 81 on a MER for Fuselage Mounting

Note: All dimensions are in inches.



Long and Short Pylons

Figure 4 - Geometric Details of a Fuselage Mounted MER and of the Long and Short Pylons

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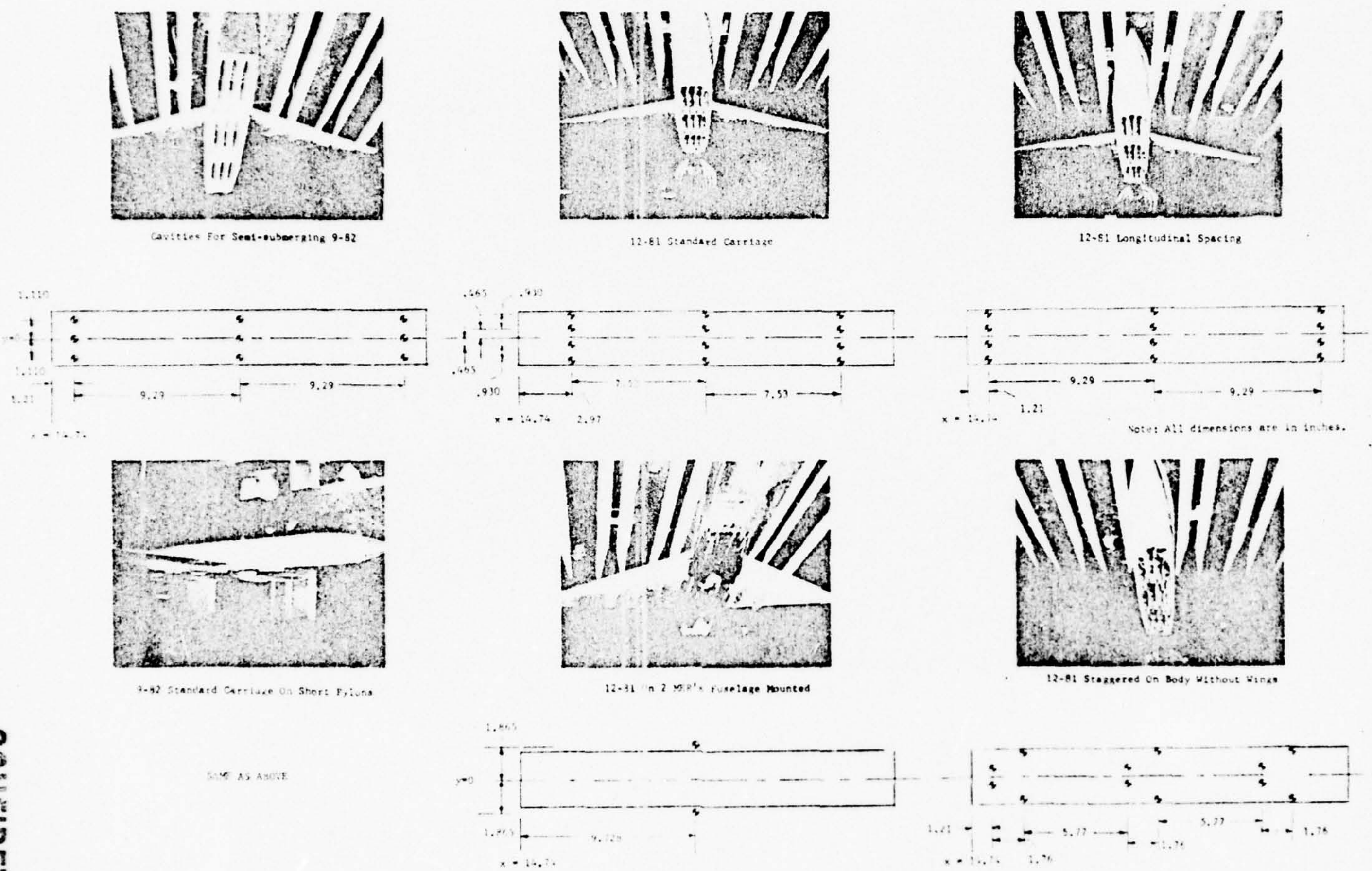

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Figure 5 - Typical Store Configurations

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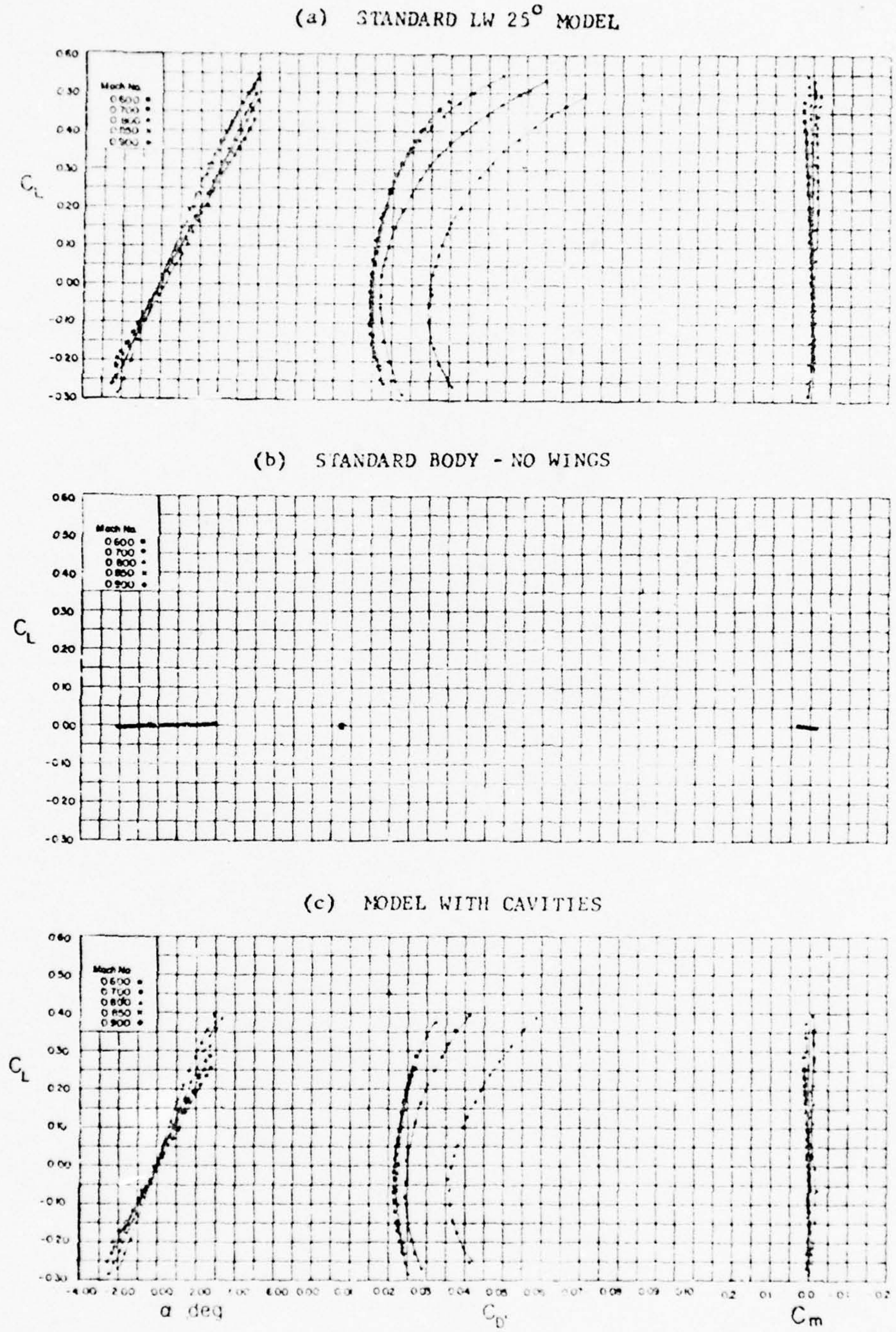
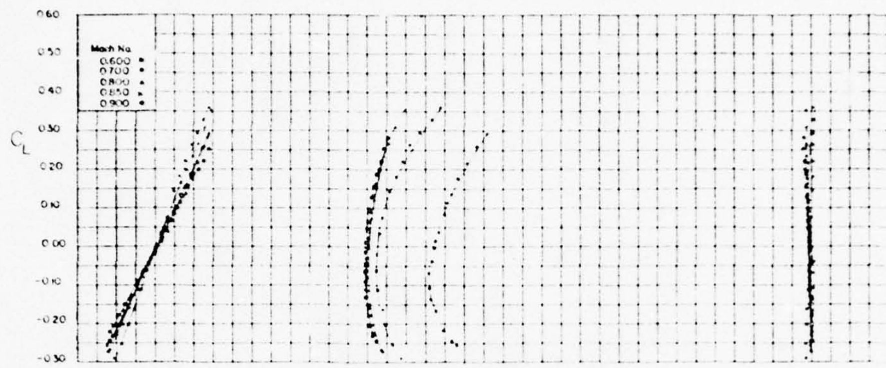
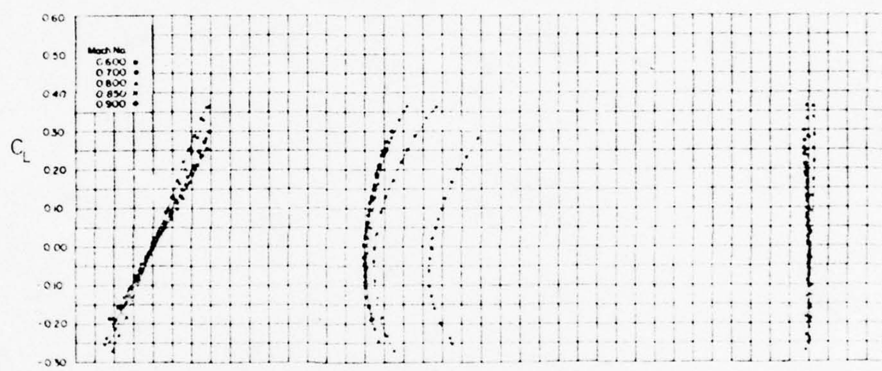


Figure 6 - Longitudinal Characteristics

(d) MODEL WITH CAVITIES FAIRED



(e) 9 SHORT FUSELAGE PYLONS



(f) 9 LONG FUSELAGE PYLONS

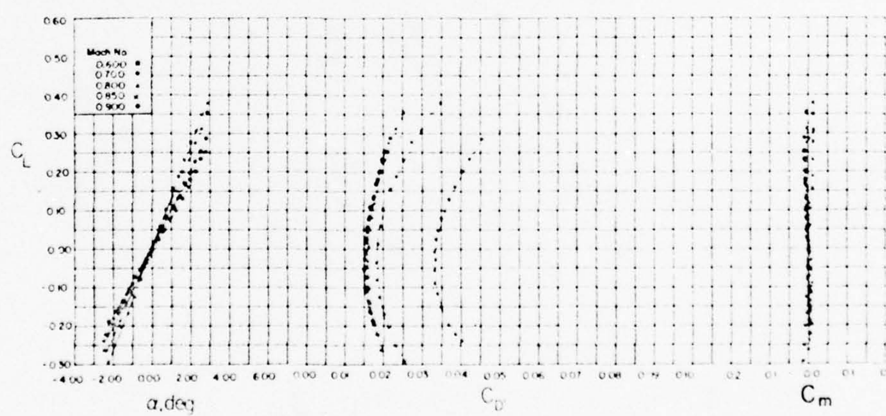
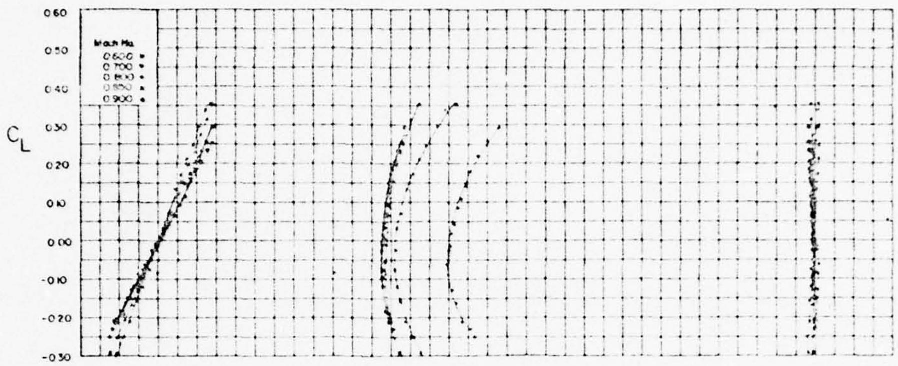
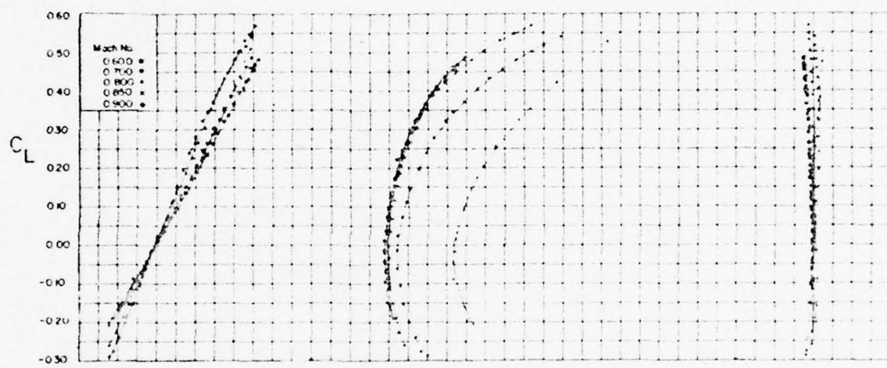


Figure 6 (Continued)

(g) 9 Mk 82 SEMI-SUBMERGED



(h) 9 Mk 82 TANGENT



(i) 9 Mk 82 TANGENT ON BODY WITH NO WINGS

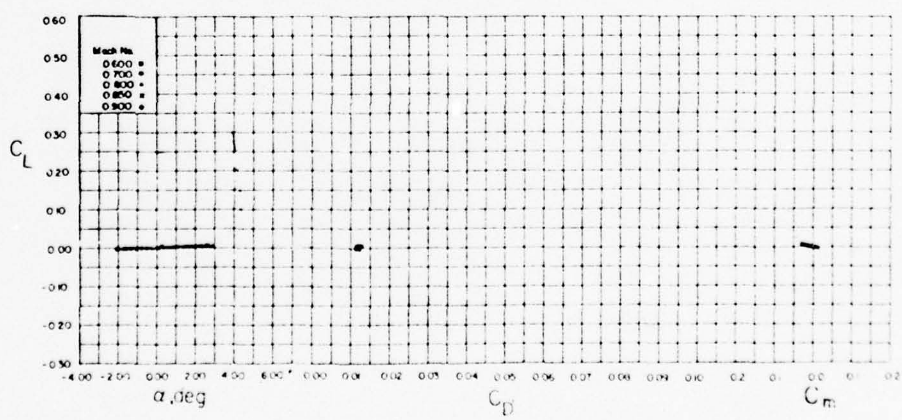
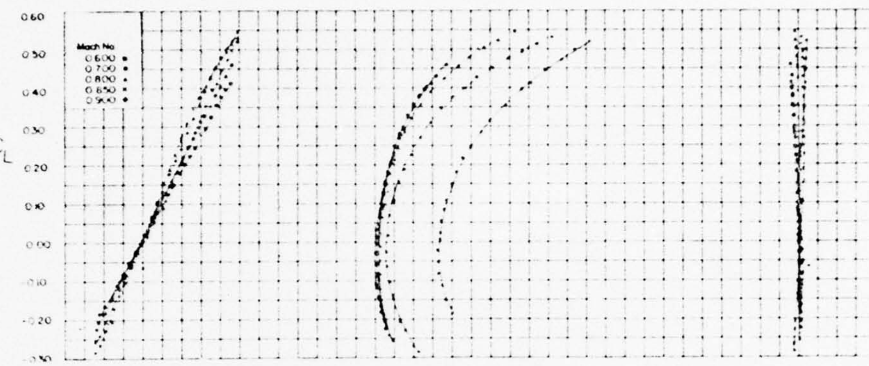
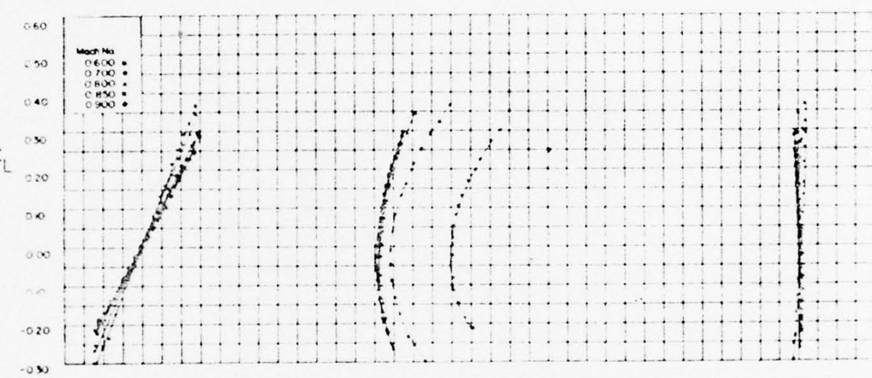


Figure 6 (Continued)

(j) 9 Mk 82 ON SHORT PYLONS



(k) 9 Mk 82 ON LONG PYLONS



(ℓ) 6 Mk 82 SEMI-SUBMERGED

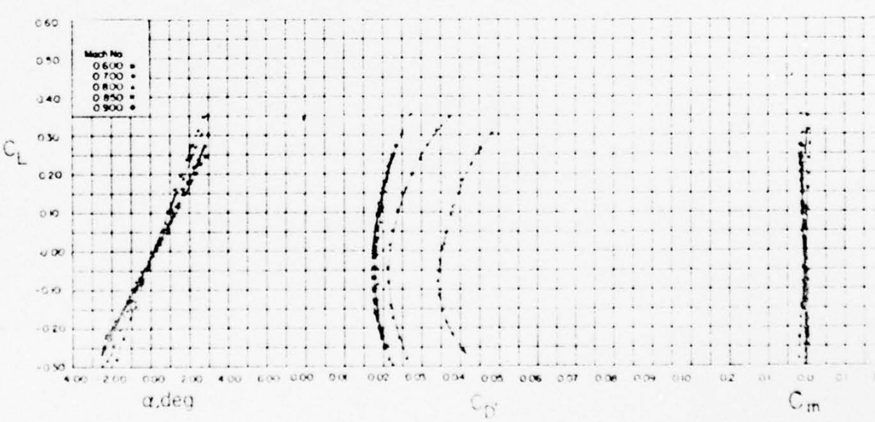
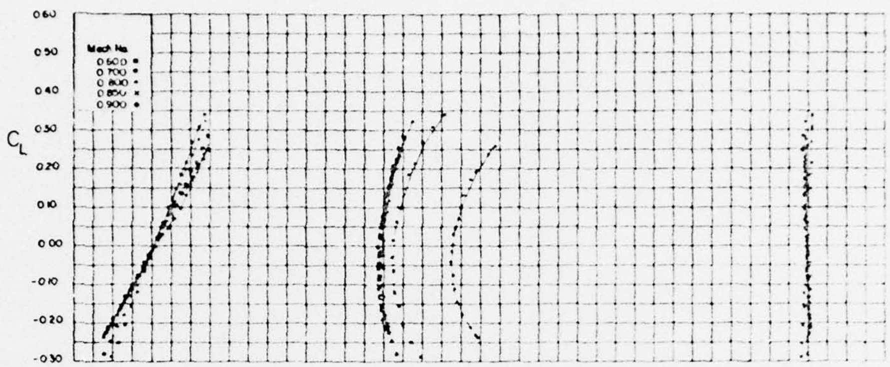
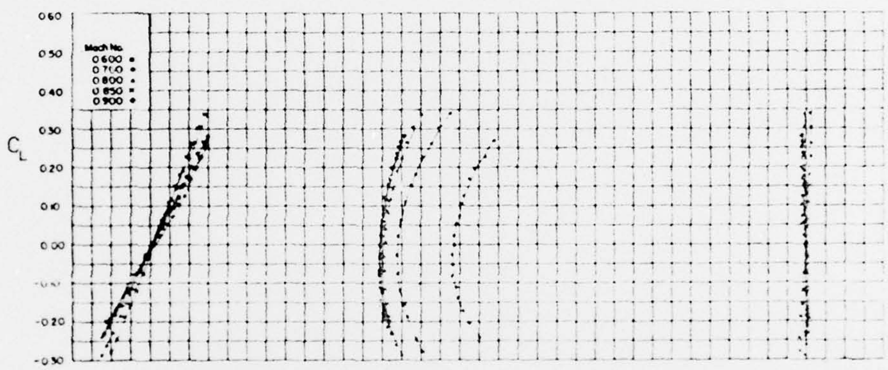


Figure 6 (Continued)

(m) 6 Mk 82 ON SHORT PYLONS



(n) 6 Mk 82 ON LONG PYLONS



(o) 3 Mk 82 SEMI-SUBMERGED

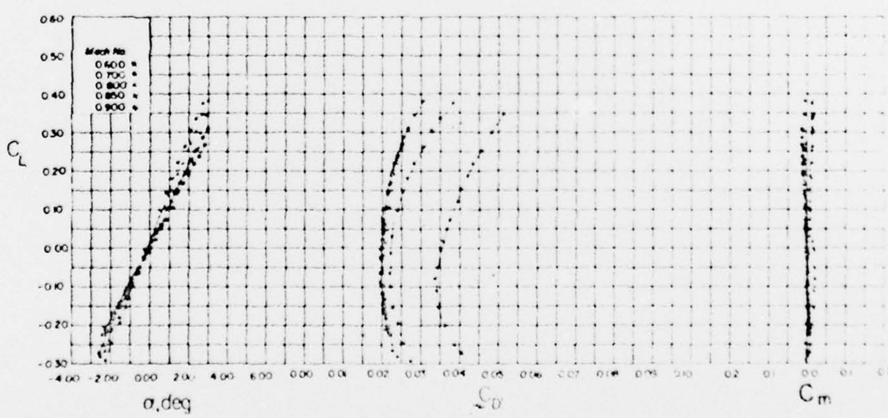
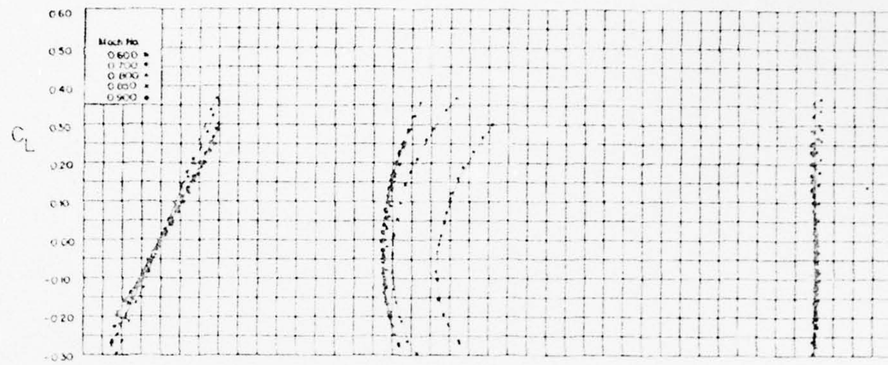
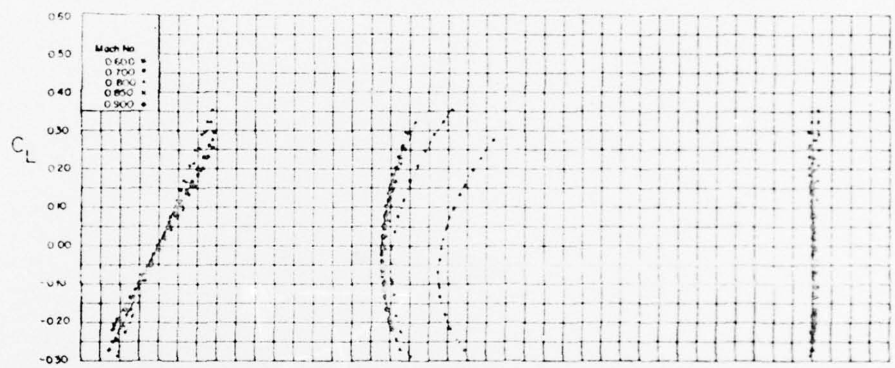


Figure 6 (Continued)

(p) 3 Mk 82 SHORT PYLONS



(q) 3 Mk 82 LONG PYLONS



(r) 12 Mk 81 TANGENT

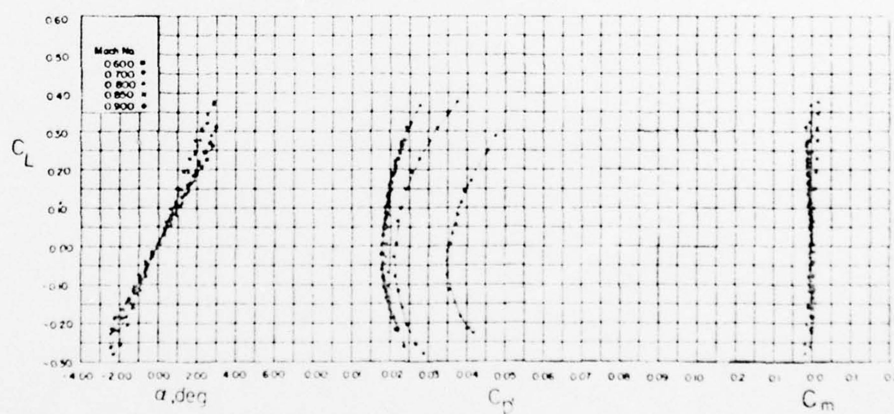
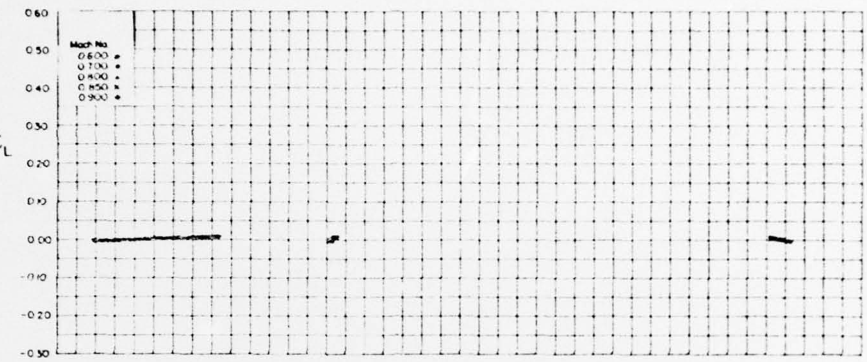
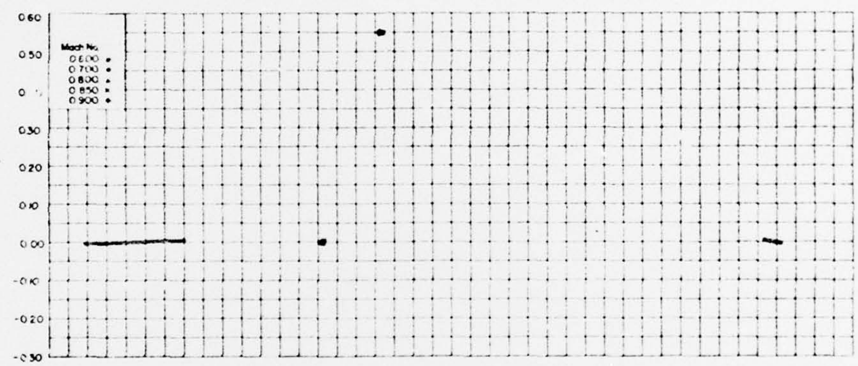


Figure 6 (Continued)

(s) 12 Mk 81 TANGENT ON BODY WITH NO WINGS



(t) 12 Mk 81 STAGGERED ON BODY WITH NO WINGS



(u) 12 Mk 81 ON FUSELAGE MOUNTED MER

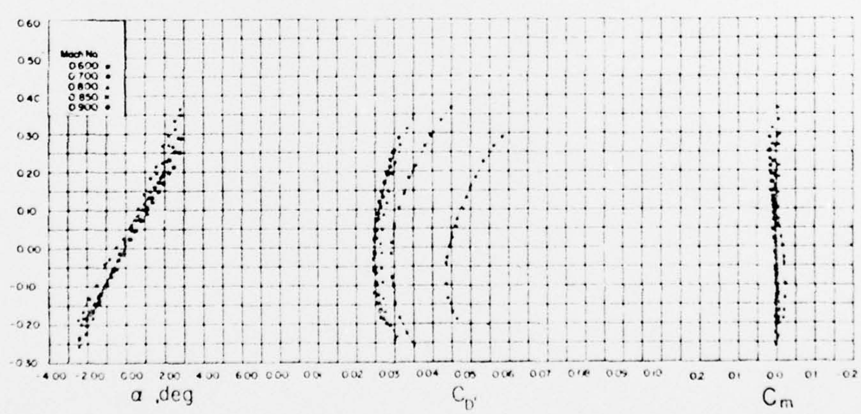
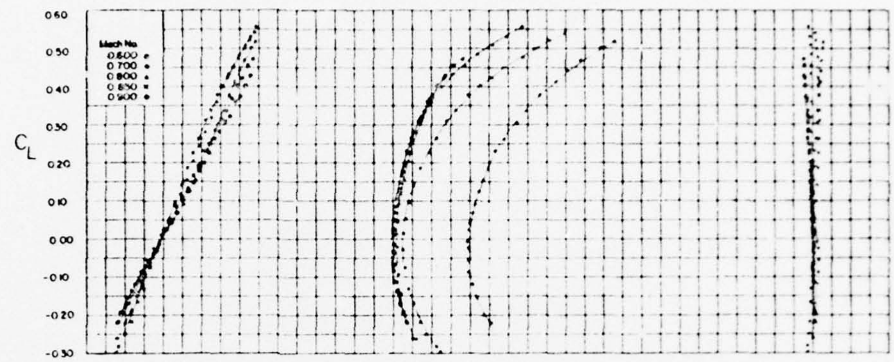
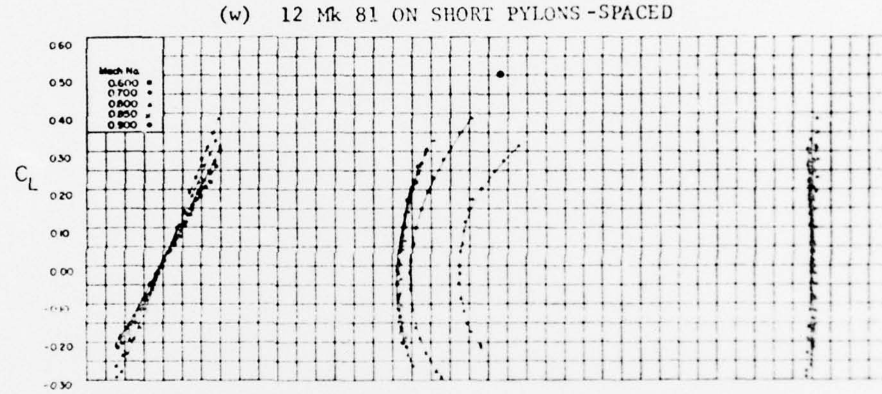


Figure 6 (Continued)

(v) 12 Mk 81 ON SHORT PYLONS



(w) 12 Mk 81 ON SHORT PYLONS-SPACED



(x) 12 Mk 81 ON LONG PYLONS

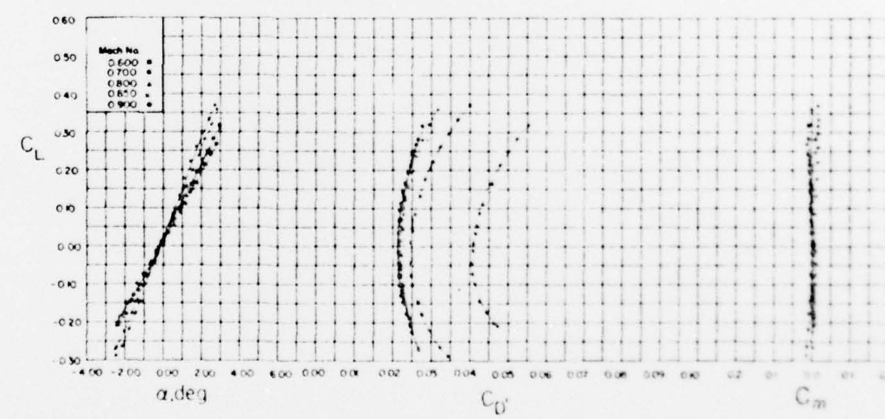
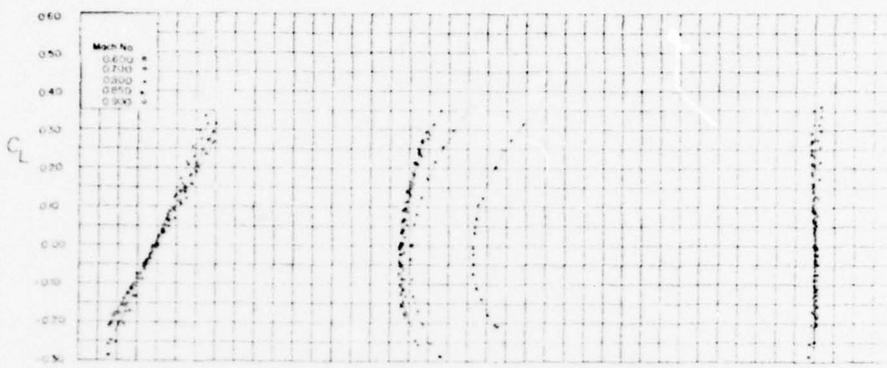
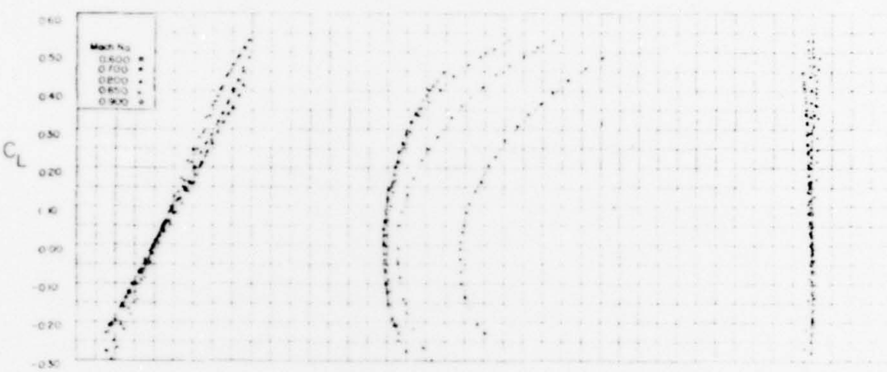


Figure 6 (Continued)

(y) 12 Mk 81 ON LONG PYLONS-SPACED



(z) 8 Mk 81 ON SHORT PYLONS



(aa) 8 Mk 81 ON LONG PYLONS

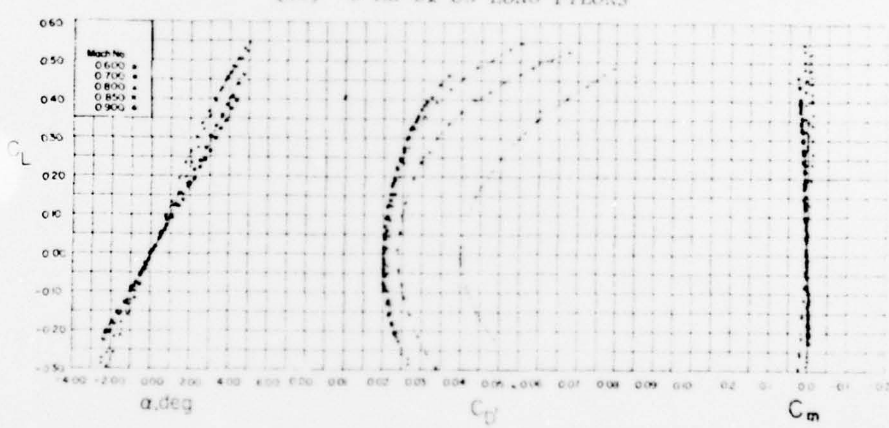
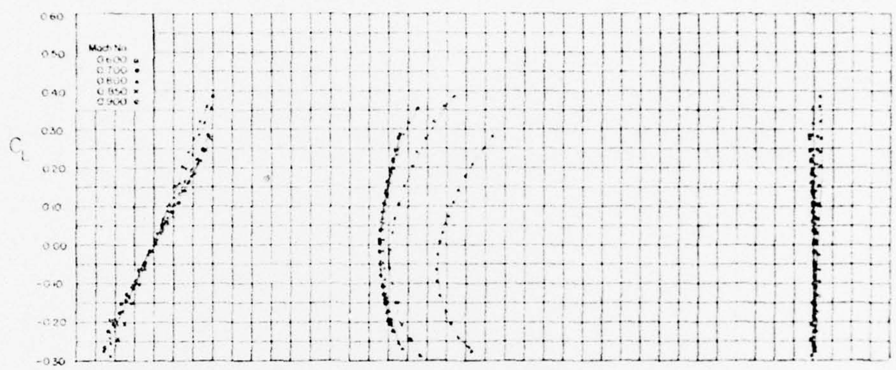


Figure 6 (Continued)

(bb) 4 Mk 81 ON SHORT PYLONS



(cc) 4 Mk 81 ON LONG PYLONS

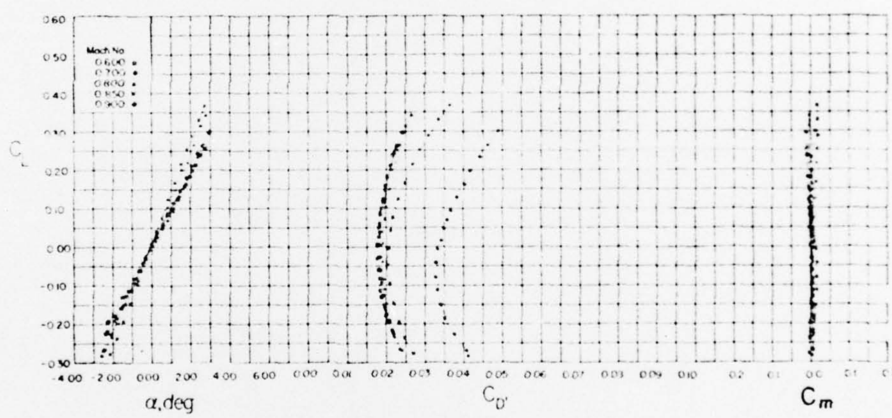
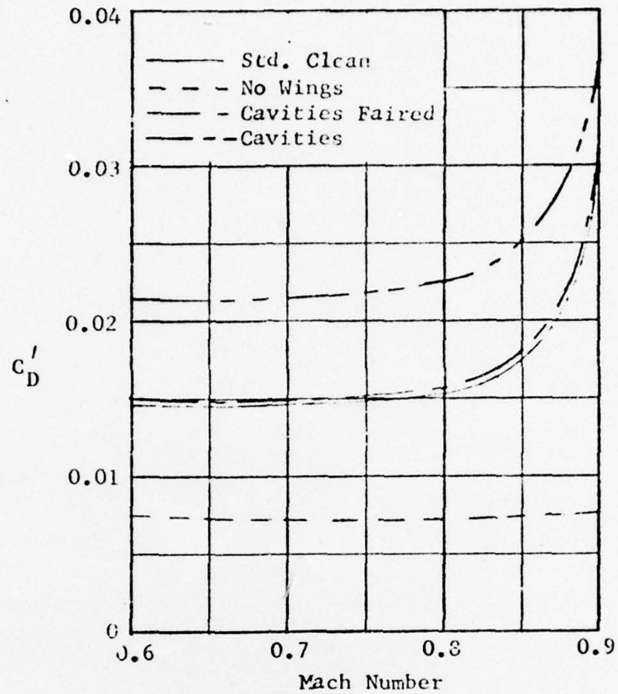


Figure 6 (Concluded)



(Drag data presented at $C_L = 0.$)

Figure 7 - Drag of Various Configurations Without Stores

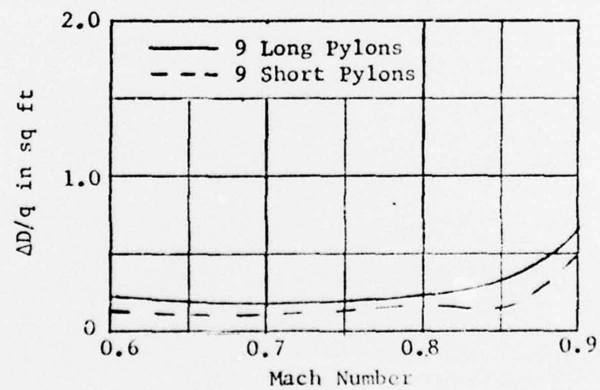


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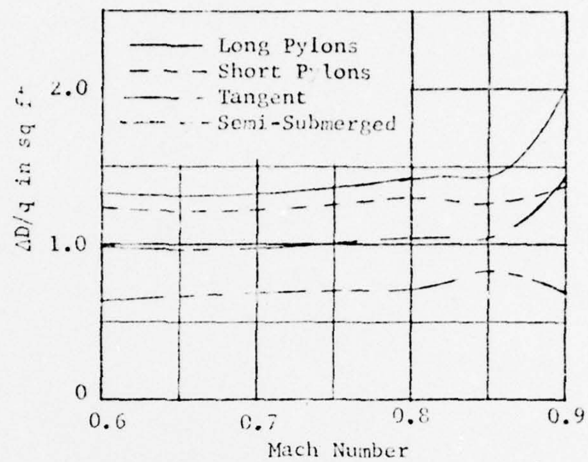
Figure 8 - Incremental Drag of Pylons



(Drag data presented at $C_L = 0.$)

Figure 9 - Incremental Drag of Various Modes of Carriage of 9 Mk 82 Bombs

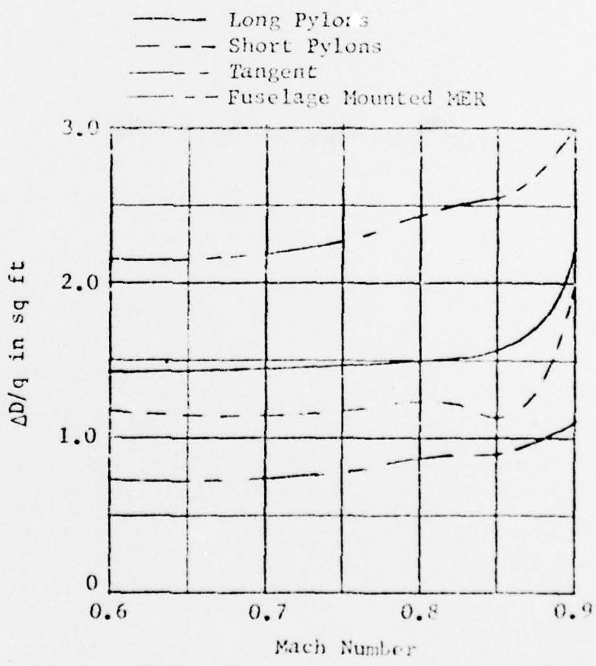


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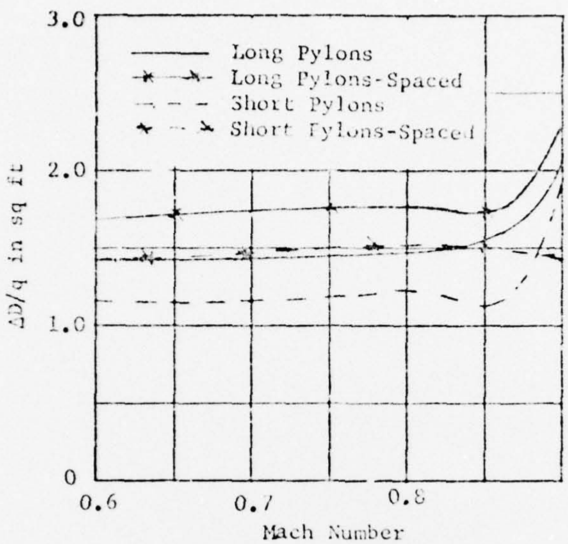
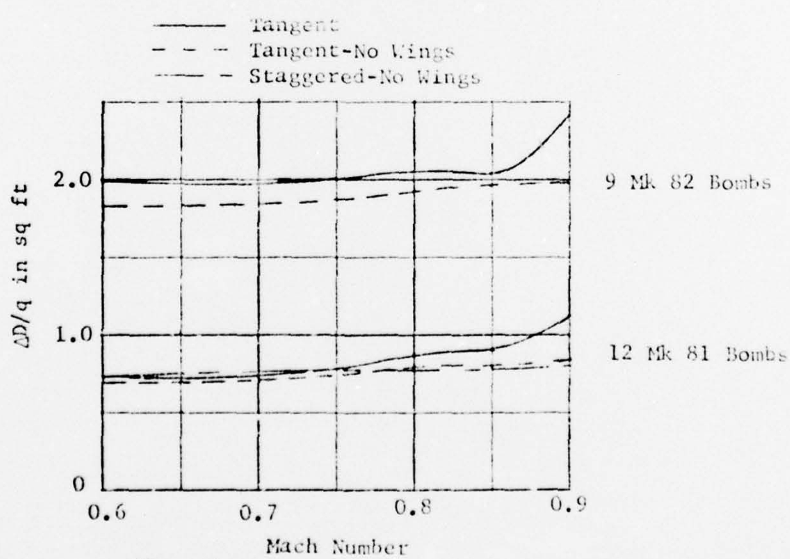
Figure 10 - Incremental Drag of Various Modes of Carriage of 12 Mk 81 Bombs



(Drag data presented at $C_L = 0.$)

Figure 11 - Effect of Longitudinal Spacing on 12 Pylon Mounted Mk 81 Bombs



(Drag data presented at $C_L = 0.$)

Figure 12 - Incremental Drag of Stores on a Wingless Body

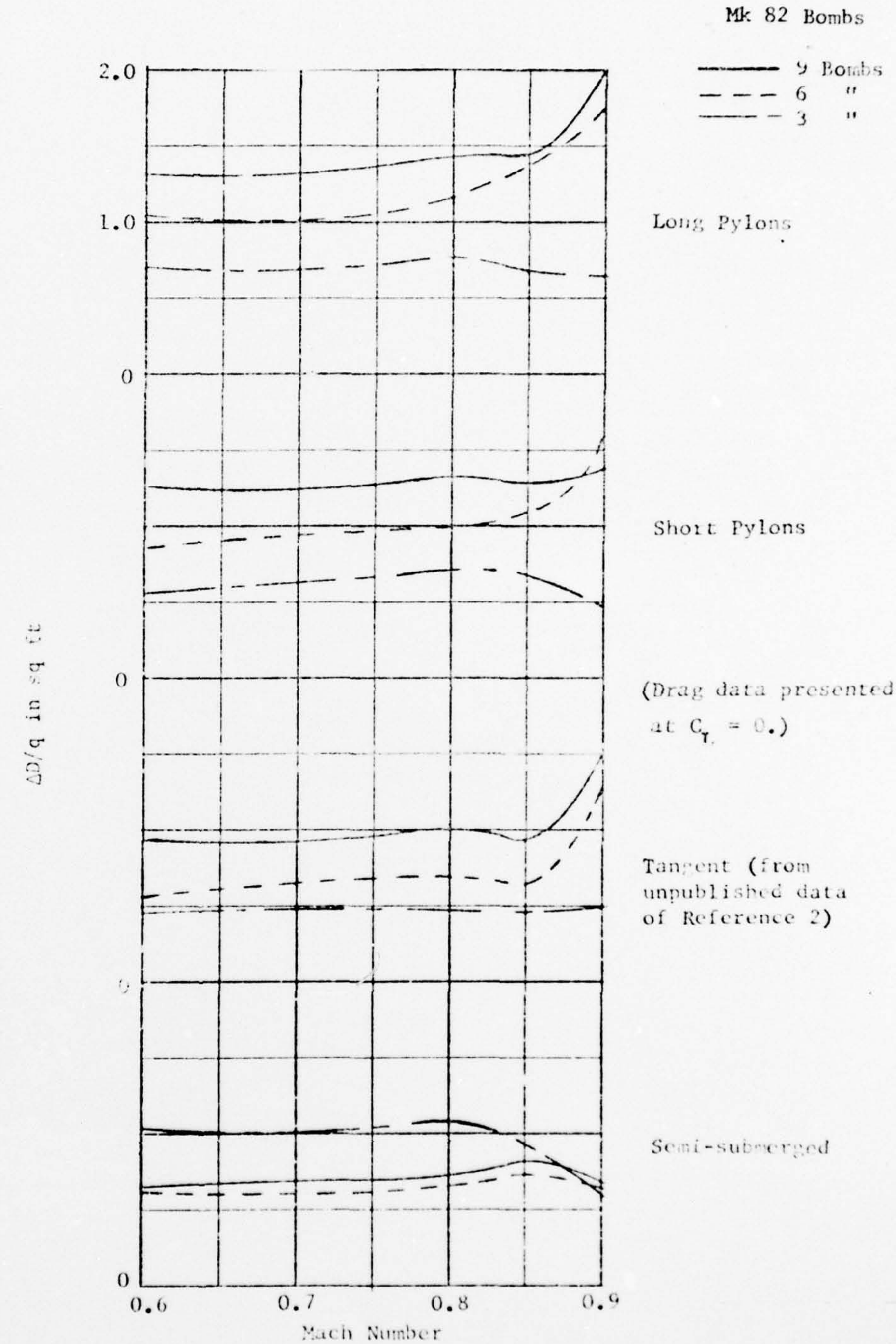
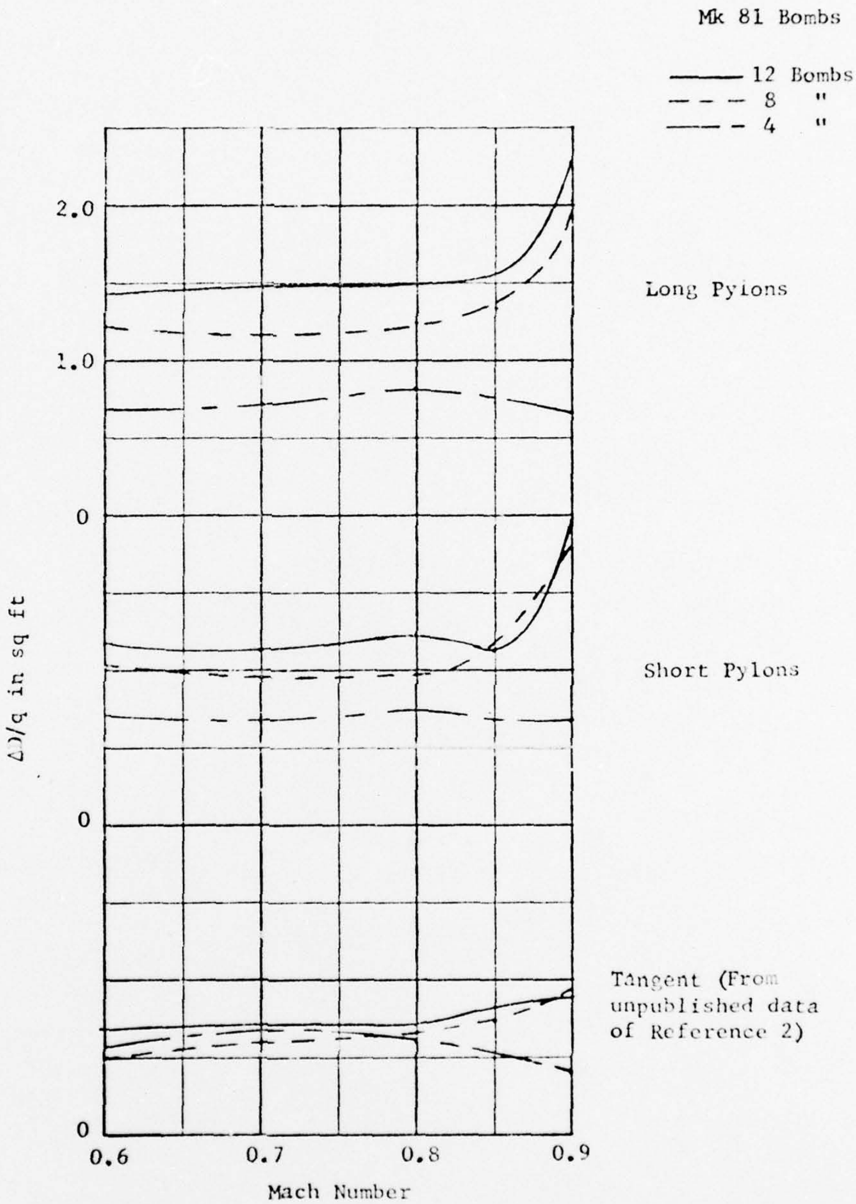


Figure 13 - Incremental Drag of Partial Loads of Mk 82 Bombs



(Drag data presented at $C_L = 0.$)

Figure 14 - Incremental Drag of Partial Loads of Mk 81 Bombs

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13. ABSTRACT

(U) The third in a series of scale-model wind tunnel tests to determine the effect of fuselage mounted stores on the drag of an attack aircraft is reported. This phase investigates stores mounted semi-submerged, tangent, and on short and long pylons on the fuselage of a low, 25° deg sweep wing. Additional configurations include stores carried on a fuselage mounted Multiple Ejection Rack (MER) as well as on the fuselage without wings. Also included in this report is the drag of partially loaded configurations. The angle of attack ranged from -2° to 4° deg and the Mach number from 0.60 to 0.90.

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Fuselage-Mounted Stores						
Store Drag						
Mk 81 Bomb						
Mk 82 Bomb						
Variation of Store Spacing and Loading						
Pylon Mounting						
Semi-Submerging						

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(PAGE 2)

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EXTERNAL STORES--
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SEMISUBMERGED--DRAG
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FLOW, CAVITY
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